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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

**Patentanmeldung Nr. Patent application No. Demande de brevet n°**

99850166.2

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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# Blatt 2 der Bescheinigung
# Sheet 2 of the certificate
# Page 2 de l'attestation

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# METHOD, APPARATUS AND COMPUTER PROGRAM IN A TELECOMMUNICATION SYSTEM

## TECHNICAL FIELD

The invention is concerned with a method and apparatus for modulating an information signal in a telecommunication system, especially for code allocation in CDMA systems using codes of different bit rates. The invention is also concerned with a computer program to carry out the method of the invention.

## BACKGROUND ART

Different channel access methods exist for the sending and receiving of digital signals. In TDMA, Time Division Multiple Access, a channel consists of a time slot in a periodic train of time intervals over the same frequency. In FDMA, Frequency Division Multiple Access, a communication channel is a single radio frequency band. Interference with adjacent channels is limited by the use of band pass filters which only pass signal energy within the specified frequency band. In contrast, Code Division Multiple Access, CDMA, allows signals to overlap in both time and frequency. Thus, several CDMA signals can share the same frequency band, but the CDMA receiver can also operate at several frequency bands.

In CDMA-technique, simultaneous connections can thus make use of a common frequency band. The selection, i.e. discrimination, between the desired signal and other signals is carried out by suitable signal processing, which is based on that the desired signal is coded with a different code than other signals. The radio channels in a CDMA system are thus obtained by using different codes for each channel. Typically, the channels are obtained by using binary PN code sequences.

The transmitted information in the CDMA radio signal is coded (spread) by a specific spreading code in the transmitter. At the receiving end, the coded information is decoded (despread) by correlating with the same specific spreading code again or by filtering the received information in a matched filter.

Second generation mobile networks systems, wherein CDMA is used, such as IS-95, were primarily designed for transferring speech signals. The CDMA frequency band used in such systems was limited in comparison with the wide band CDMA system, WCDMA, which will be used in the third generation mobile system, UMTS, for transferring different services with signals of a wide spectrum of bit rates, such as speech, video and other services.

In WCDMA systems, user channels can be assigned binary code sequences of varying length based on the data rate of each channel. This allows for different services, e.g. speech, video, data etc. Orthogonal codes are codes that do not correlate to eachother at a given time offset. Using such codes will therefore discriminate desired channels and the use of orthogonal codes will reduce the interference. Normally, the interference will not be completely eliminated as e.g. time dispersion will partly destroy the orthogonality between signals coded with orthogonal codes.

Different code structures exist, in which all available codes in a system are arranged, usually after the bit rate they provide. Examples of code structure systems used in WCDMA are e.g. the OVSF codes, explained in the following. One way of creating OVSF codes is by means of Walsh codes of different lengths (i.e. different spreading factors).

In the international patent application WO 9503652, user channels are assigned binary Walsh code sequences of varying length based on the data rate of each channel.

The lowest possible order (i.e.first order) of such a code, called a root code, has a code length of one bit, and may be equivalent to "0". A tree of Walsh sequences may be envisioned as a set of interconnected nodes each having two branches, where all of the nodes may be traced back to the root node. Then the two branches from this root node will be connected to a pair of nodes defined by Walsh sequences "00" and "01", which are called second order codes. This process can be continued by deriving a Walsh function matrix by branching the node "00" into the nodes "0000" and "0011", and branching the node "01" to ""0101" and "0110" which are called third order codes. The Walsh sequence defining a node of the tree branching from a given node is not orthogonal to the Walsh sequence associated with that node. Therefore, associated nodes of different orders do not discriminate channels and branch-connected codes may not be simultaneously used. Any other Walsh sequences defining nodes not connected to the given node can be simultaneously used as codes to define other mobile channels.

The amount of codes to be allocated is thus restricted, as the number of available codes for a specific code length is mathematically limited. Orthogonal Variable Spreading Factor (OVSF) codes are downlink channelisation codes used in WCDMA that preserves the orthogonality between channels of different rates and spreading factors. The code structure of the OVSF codes are described by means of a code tree structure, which is illustrated in figure 1 and explained in the corresponding text on pages 7 - 8. The code tree structure has to be understood so that, services requiring longer length codes, like speech, are to the right of the code tree, whereas more requiring services (i.e. requiring higher data rates), like video, needs codes of shorter lengths seen to the left of the code tree. In cells able to provide different kinds of services, codes of different spreading factors and rates will be requested, corresponding to different services.

Prior art solutions for allocation of codes in CDMA systems, able to provide speech and other services, in which the codes to be allocated are selected systematically, are not known by the applicant. If the allocation of codes is

performed by just signing the first available free code without any further rules, it represents the simplest way to allocate such code requests, the so called sequential mode.

Problems in using such sequential code allocation methods in wide band systems using several code levels (orders) arise upon releasing the used codes when older calls expire, which results in holes in the code structure of busy codes. Even if the maximum total bit rate available has not been reached (i.e. there are still some free codes), new high bit rate call requests might not be satisfied unless used lower bit rate codes are reallocated in order to free a higher bit rate code of requested level. Since reallocations need signalling between the base stations and the involved mobile stations, critical situations might arise in high load conditions.

In the international patent application WO 95/03652 (QUALCOMM INCORPORATED), proposing a code allocation system for wide band CDMA systems, this problem has been discussed and the idea of minimizing the number of disqualified shorter-length codes is presented. The document states the opportunity of assigning codes that are related to busy codes, in order to minimize the fragmentation of the tree and suggest to allocate slow codes that are related to unavailable fast codes. Furthermore, reallocation is presented to increase the availability of fast codes. A precise algorithm to achieve this result is, however, not presented and the problem of future availability is not taken into account. Thus, there is a need for such an algorithm.

An object of the invention is to develop a method, which minimizes the signalling in the system when allocating codes in a multi speed system.

Another object is to reduce the setup delay when allocating new calls.

A third object is to develop a method, which maximizes the amount of available free codes at different levels.

A fourth object is to develop a method for reallocation when no free codes are available, but to minimize the need for such reallocation.

A fifth object of the invention is to develop a method with which a minimum of higher-rate codes become unavailable by using an algorithm to carry out the allocation of the invention.

## SUMMARY OF THE INVENTION

The method of the invention for modulating an information signal in a telecommunication system, which communication system makes use of spreading codes in the modulation to discriminate between user signals, the codes being allocated for incoming requests by selection from one or more code structures having codes of different bit rates, is characterized by the steps of noting the bit rate of a code to be allocated for an incoming request, determination of the availability of the different codes having the desired bit rate, and allocating a code in accordance with pre-selected rules by taking the availability of the different codes into consideration in a way leading to an optimal use of the code structure(s).

The apparatus of the invention comprises means for performing the method of the invention.

The algorithm of the invention performs the allocation method of the invention in form of a computer program in accordance with certain rules.

The codes allocated for a given service request also depend on the traffic situation, the number of available codes and the requested bit rate of the code.

A condition for the allocation of the code is that the traffic situation allows the allocation so that the maximum transfer capacity of the system is not exceeded. If a code system with available transfer capacity is not available, the incoming request has to be blocked.

If only one free code of the requested level exists, that code is allocated for the request.

If more than one free code of the requested level exist, the algorithm of the invention used for allocation of the codes, chooses the code to be allocated in accordance with pre-selected rules prioritizing some codes in front of others.

If there, however, does not exist any free codes of the requested level but there are enough transfer capacity left in the system for a specific service request (some free codes), the reallocation algorithm of the invention performs a reallocation of already assigned codes to get a free code of the requested level. The incoming request is in this case assigned to a code, which is unavailable because of used related longer length codes. The reallocation of these used, already assigned codes is then carried out according to same rules as the allocation of a code for a new incoming request.

The incoming request can be any service, used in a WCDMA system, for example speech, data, video etc.

By means of the invention, an algorithm can be indicated, that, given an offered traffic statistics, minimizes the number of cases in which reallocation is needed in order to assign new codes or the total number of changes of already allocated codes. Consequently, the total signalling in the system will be decreased.

In the following the invention is described by means of a block scheme and examples. The rules according to which some codes are prioritized in front of

others are explained by means of the block scheme and the examples. The invention is, however, not restricted to the details of the following description, which is presented for illustrative purposes only. The idea of the invention, which is defined in the claims, can e.g. be extended to other code system structures defining different levels of codes than the OVFS code tree, even if this particular structure is described in the figures.

## BRIEF DESCRIPTION OF DRAWINGS

Figure 1 illustrates an example of an OVSF code tree structure

Figure 2 is a block scheme of the principle of the invention

Figure 3 – 7 presents the application of the algorithm of the invention in different hypothetical situations

## DETAILED DESCRIPTION

The OVSF codes are defined by a code structure in figure 1. Each node of the tree corresponds to one code, whose spreading factor (SF) and rate is defined by its SF level 1, 2, 4, 8 or 16. Code levels can also be defined by so called levels k to make the description easier. SF –levels are related to k-levels in such a way that SF levels 1, 2, 4, 8 and 16 corresponds to k-levels 0, 1, 2, 3, 4 respectively. A code of a given level has a given length and thus corresponds to a given spreading factor and a given bit rate. The node representing the lowest SF or lowest level k is called the root, i.e. the node to the very left in fig.1. A code is free (and can thus be assigned to an incoming call) if no code in its subtree (the subtree to which the code is root) and in the branch that leads from it to the tree root is busy.

A code can be busy, unavailable or free, depending on the degree of occupation. A code is *busy,* if the code itself, or a higher rate code on the path from the code to the root, already has been assigned to a downlink connection. A busy code is said to be *used* if it is directly assigned for a downlink connection. A code is *unavailable*, if one or more codes in the subtree of the code are busy. If the whole subtree is used, the unavailable code can be considered busy. All remaining codes, which are neither busy nor unavailable are *free*.

The shorter length (higher bit rate) code from which two codes descend with double length is called *father* to these codes and the two descendant codes are called *sons*. Codes having the same father are *brother* codes.

The code tree structure has to be understood so that, services requiring longer length codes, like speech, are on the right hand side of the code tree, whereas more requiring services, like video, needs codes of shorter lengths (which means higher bit rates) are on the left hand side of the code tree.

Figure 2 is a block scheme of the principle of the invention. When an incoming request for allocation of a code for the spread information signal is received in step 1, there is first noted the desired level $k$ (or the desired bit rate) for the signal code in step 2. The lowest-level code (the root code) of the code tree, typically used in a cell in a cellular radio system, defines the total maximum transmission capacity for that cell, which should not be exceeded. Exceeding the total maximum bit rate would determine non-orthogonality between some codes and their consequent degradation. Requests are blocked or assigned to additional code trees if the total (already) used bit rate plus the arriving call bit rate exceeds the total tree bit rate. If it is considered in step 3 that the allocation of a code for the incoming request would exceed the maximum total bit rate of the root code of the code tree, the request is blocked in step 4 or assigned to another code tree, if other code trees are used in the system.

If it is in step 5 considered that the maximum total bit rate is not exceeded, but that no free codes of desired level $k$ exist, reallocation is needed, which means, that the incoming request is assigned to an unavailable code of requested level in accordance with step 6 of figure 2, and that the already assigned subtree codes relating to this unavailable code have to be changed in step 7 of figure 2 so that this code of desired level $k$ would be free.

In the reallocation procedure of the invention, the incoming request should therefore be assigned to a preferred unavailable (but not busy) code in accordance with pre-selected rules, after which the used codes in its subtree have to be reallocated.

The reallocation is preferably done by an algorithm which aims at minimizing the number of needed reallocations (defined as changes of the assigned codes of ongoing connections, or equivalently as the number of removed codes to be reallocated as a consequence of the reallocation procedure).

The preferred unavailable code assigned in step 6 is the one that has the lowest number of assigned codes in its subtree (the lowest number of related higher-level k codes), to prepare for a low number of reallocations (changes in the assigned codes in ongoing connections). The preferred unavailable code might also according to another embodiment of the invention be the one that has the lowest unavailability with respect to its subtree.

The best mode, in which the preferred unavailable code is the one that has the lowest number of assigned codes in its subtree, minimizes the number of cases in which reallocation is needed.

Reallocation of the subtree codes is then performed following the same rules that apply for a new incoming request in accordance with steps 5 –11 of figure 2: if free codes of the corresponding level exist, according to the allocation algorithm, if no free code exists, according to the reallocation algorithm.

If it is in step 5 considered that, there is one free code of requested bit rate, that code is allocated. If more than one free codes of the desired level exist, the availability degree for the codes of the requested level is determined in step 8 of figure 2 to select a code by prioritizing according to pre-selected rules in step 9 of figure 2. According to these rules, the highest possible number of lower level k available codes is preserved (step 10 of figure 2) and, in case of several choices, probability of future release of a lower level code (step 11 of figure 2) is preferably also maximized according to pre-selected rules in step 9 of figure 2.

The prioritizing of codes preserving the highest number of free codes on lower levels (step 10 of figure 2) is e.g. performed by defining a set of available codes having fathers with highest unavailability levels, and by repeating the foregoing step for code levels of successively former generations until the root code and finally choosing the code from the resulting subset.

It should be noted that through allocation and reallocation a new code request can always be satisfied, unless it exceeds the total capacity of the tree in term of bit rate.

## EXAMPLES

In the following examples 1 – 5, the invention is explained in connection with some typical situations (cases 1 – 4). In all figures 3 – 7, black circles represent used codes, while light grey ones represent busy (but not used) codes. One code is used if one request is assigned to it; it can be busy without being used if one of its ancestors is used.

EXAMPLE 1 (present availability, case 1)

Figure 3 presents a hypothetical situation, wherein OVSF codes are allocated for incoming requests. In figure 3, black circles represent used codes and light

gray circles represent busy codes. Four levels *k* of codes 0,1,2,3 and 4 are indicated in figure 3, the lowest level 0 corresponding to the highest bit rate. Free codes in the highest level are identified by capital letters A – M.

An incoming request of the lowest level (k = 4) of the code tree of figure 3 is now assumed (steps 1 and 2 of figure 2). If the maximum total bit rate or the transfer capacity of the code tree is not exceeded, (step 3 of figure 2) and there are free codes of the requested level (step 5 of figure 2), the algorithm of the invention considers the unavailability level of each free code's father (step 8 of figure 2), that is ½ for C and zero for all the remaining free codes, which means that C is chosen for assignment to achieve the aim in accordance with which the highest possible number of lower level available codes are preserved (CLAIM 5) (step 10 of figure 2). This is the best solution for resulting higher bit rate codes, which is 6 free codes on level k=3, 2 free codes on level k=2, 1 free code on level k=1. For the remaining possibilities to choose a higher level k code among F-M, there are 5 free codes on level k=3, 1 free code on level k=2 and no free code on level k=1. For assignments A-B, there are 5 free codes on level k=3, 2 free codes on level k=2 and 1 free code on level k=1.

EXAMPLE 2 (Future availability, case 2)

Figure 4 presents another hypothetical situation, wherein OVSF codes are allocated for incoming requests. Like above, black circles represent used codes and light gray circles represent busy codes as in figure 3. Four levels *k* of codes 0,1,2,3 and 4 are indicated, the lowest level 0 corresponding to the highest bit rate. Free codes in the highest level k are identified by capital letters A – E.

An incoming request of level k = 4 is now assumed (steps 1 and 2 of figure 2). If the maximum bit rate or the transfer capacity of the code tree is not exceeded, (step 3 of figure 2) and there are free codes of the requested level (step 5 of figure 2), the availability degree for the free codes are determined (step 8 of figure 2). The OVSF tree of figure 4 presents 5 free codes on level

k = 4, which are A, B, C, D and E. Codes C and D have a free father (zero unavailability), so they should be discarded to leave as much higher bit rate codes free as possible (CLAIM 5) (step 10 of figure 2 ).

Codes A, B and E have "half" unavailable fathers, so the algorithm considers their grand-father's unavailability, that is ¾ for codes A and E and ¼ for code B. This last should then be discarded( step 10 of figure 2). Next step is to consider great grand-fathers (level $k$ = 1). The ancestor of code A has unavailability 4/8, while the ancestor of code E has unavailability 7/8. Code E should then be allocated to the incoming request (CLAIM 7) (step 11 of figure 2).

It is worth noting that codes A, B and E are equivalent from a lower k free codes results from each assignment. In a preferable embodiment of the invention (step 11 of figure 2) the allocation of a code is performed by maximizing the probability of future release of a lower level code. The difference between codes A, B and E thus concerns the probability of a short term release of a presently unavailable lower-level code, that is maximized through the proposed choice (CLAIM 6) (step 11 of figure 2).

EXAMPLE 3 (Reallocation, first embodiment, case 3)

Figure 5 presents still another hypothetical situation, wherein OVSF codes are allocated for incoming calls. An incoming request of level k = 1 is now assumed to be allocated (steps 1 and 2 of figure 2). If the maximum total bit rate or the transfer capacity of the code tree is not exceeded, (step 3 of figure 2), the availability degree of the codes of requested level is determined (step 5 of figure 2). Since according to this analysis (step 5 of figure 2), no free codes are available, a reallocation algorithm is performed according to which one of the two unavailable codes (A or B) has to be chosen to be assigned for the incoming request (CLAIM 9) (step 6 of figure 2). Code A has two used descendants (D and E of level k = 4), while code B has only one used son (C, of level k = 2, so this last one is preferred according to the rule of the present invention saying that the reallocation is performed by minimizing the number

of changes of already allocated codes and that the preferred unavailable code is the one that has the lowest number of assigned related higher-level codes (CLAIMS 10,11).

Once the choice of code B is done, the higher level code C has to be reallocated, as is shown in figure 6 (CLAIM 13). The reallocation request for performing the reallocation of code C (level $k = 2$) is treated as an incoming request (request from step 7 to step 5 in figure 2).

Since no free codes are available, once again the reallocation procedure is triggered, and one of the two unavailable level $k = 2$ codes is chosen (indifferently in this case, since they have the same unavailability). One of the related level $k = 4$ codes then has to be moved away from the subtree of the assigned code, and in turn allocated as an ordinary incoming request. In this last assignment the reallocation of one of the level $k = 4$ codes is performed so that they both are in the same subtree with respect of level $k = 2$, which is not related to the reallocated code C, (and preferably also in the same subtree with respect of $k = 3$ to leave an extra level $k=3$ code free).

EXAMPLE 4 (Reallocation, second embodiment, case 3)
Instead of using the reallocation method of example 3, a different reallocation procedure is used for the same situation as in example 3.

The reallocation now assumed chooses the lower unavailability level subtree (CLAIM 14). The unavailability for A is 2/8 and for B ½. (Figure 5). In that case, code A would be chosen instead of code B, leading to no additional reallocation steps in addition to the reallocation of codes D and E.

However, two code changes (reallocations) were needed, just as in the previous case, so assuming that indirect reallocation procedures do not determine additional setup delay (this assumption is justified by the possibility the base station has to perform internally all needed reallocation, and just at the end issue the actual code change commands to involved mobile stations),

the performance of the two reallocation algorithms in the above examples 3 and 4 is the same.

EXAMPLE 5 (second embodiment, case 4)

The second embodiment of the reallocation method of the invention is now used for the situation is figure 7.

As the allocating according to this embodiment is performed depending on the unavailability levels (CLAIM 14) instead of the bare unweighted number of allocated codes as was done in the first embodiment in example 3, we would choose once again code A instead of B, for its unavailability level 3/8 is lower than that of code A ½. Indeed, this is not the better choice in this situation, since it determines three code changes (changing of codes D, E and F in figure 7), while only two would be needed choosing code B, i.e. using the proposed, bare number of codes based, algorithm according to the first embodiment.

The two above examples intend at illustrate how the proposed algorithm works, based on the number of used codes in the subtrees and to show that a possible alternative algorithm (based on the unavailability level of the subtrees instead) that performs in the same way in the situation depicted in example 3 may lead to additional unneeded code changes in other cases, such as in example 4.

A good embodiment is to choose the subtree with the lowest number of used codes and if more than one subtree has the same lowest number of used codes, choosing among that subset that one that has the lowest unavailability level. (CLAIM 15)

**PERFORMANCE EVALUATION**

Simulations have been carried out to evaluate the improvement in code allocation performance of the proposed solution of the invention.

Different services have been considered, with Spreading factors ranging from 4 (384 kbps LCD (Long Constrained Delay Data) and 2048 kbps UDD (Unconstrained Delay Data)) to 128 (8kbps Speech). Offered traffic statistics during simulation time (10000s) are reported in table 1.

Five different combinations of allocation and reallocation algorithms have been tested with the same offered traffic conditions. In the following the solution of the invention is called "proposed" and the solution of prior art, described on page 2 is called "sequential". Tables 2, 3, 4 and 5 show the simulation results (service by service) respectively using sequential allocation and reallocation, sequential allocation and proposed reallocation, proposed allocation and sequential reallocation, proposed allocation and reallocation. (the embodiment of claim 11 is used in the reallocation). In the method of the sequential allocation, the first free available code is assigned without any further rules.

In the first column, the number of allocations blocked due to lack of free space in the tree is reported. The number of requests that can be satisfied, eventually by reallocation follows. Since each request is served if and only if there is theoretical room in the tree (regardless of how free codes are distributed), and the offered traffic is the same (the same seeds for its random generation have been used), the number of blocked and admitted calls is the same for all cases. The simulations for the different algorithms were performed in the same conditions, not just statistically speaking, but in the same punctual conditions of tree operations. In the third column, the number of reallocations procedures can be found. Finally, in the fourth column, the total reallocations needed are presented.

The number of reallocation procedures represents how many times a new code request could not be satisfied picking up directly one free code from the tree, and a call to the reallocation algorithm was therefore unavoidable.

Keeping constant all other parameters, this value decreases as the performance of the allocation procedure improves.

From a system point of view, the number of reallocation procedures determines an average setup delay for the incoming calls due to the need for code changes.

On the other hand, assuming that all code changes can be performed simultaneously, the number of total reallocations is proportional to the generated signaling overhead.

Tables 6 and 7 show the comparisons in terms of number of reallocation procedures and total reallocations using the different algorithm combinations.

The improvement provided by the proposed algorithms is evident in term of both avoided reallocation procedures (and thus lower average setup delay) and avoided code changes (and thus lower signalling overhead).

The solution of the invention, when both the allocation and reallocation is performed by using the algorithms of the invention, (P.A.P.R. is used) provides a decrease of the reallocation procedure of 45% (from about 4500 to about 2500), and correspondingly a decrease of the code changes of 74% (from about 13500 to about 3500) with respect to the sequential allocation and reallocation case of prior art.

The proposed allocation and reallocation algorithms of the invention determine the decrease to about one fourth of the number of code changes in a loaded system (compared to the simple sequential procedures of prior art),

correspondingly reducing the involved signaling messages. This can be seen in table 8, comparing S.A.S.R. (total 13487) with P.A.P.R. (total 3507)

In the same way, the number of reallocation procedures needed is almost reduced to a half, with positive impacts on setup delays due to code changes. The cost of the solution of the invention is likely to be represented only by a slight increase on the computational complexity needed at the base station as the base station anyway has to use some algorithm for the code allocation.

| k | SF | Sym. rate [kbps] | Service | Arrival rate [$s^{-1}$] | Mean st. time [s] |
|---|---|---|---|---|---|
| 0 | 1 | 4096 | LCD 2048 (4 k=2 codes) | - | - |
| 1 | 2 | 2048 | - | - | - |
| 2 | 4 | 1024 | LCD 384 – UDD 2048 | 0.0125 | 10 |
| 3 | 8 | 512 | UDD 384 | 0.025 | 10 |
| 4 | 16 | 256 | LCD 144 | 0.1 | 10 |
| 5 | 32 | 128 | UDD 144 | 0.4 | 10 |
| 6 | 64 | 64 | LCD 64 – UDD 64 | 1.6 | 10 |
| 7 | 128 | 32 | Speech | 6.4 | 10 |
| 8 | 256 | 16 | CCPCH | - | - |

**Table 1:** Per service offered traffic statistics.

| K | SF | Blocked Requests | Admitted Requests | Reallocation Procedures | Total Reallocations |
|---|---|---|---|---|---|
| 2 | 4 | 105 | 7 | 7 | - |
| 3 | 8 | 142 | 106 | 99 | - |
| 4 | 16 | 288 | 714 | 610 | 38 |
| 5 | 32 | 535 | 3426 | 1779 | 458 |
| 6 | 64 | 1065 | 14875 | 1951 | 1839 |
| 7 | 128 | 2073 | 62091 | - | 11152 |
| Total | | 4208 | 81219 | 4446 | 13487 |

**Table 2:** Sequential allocation and reallocation (S.A.S.R.).

| K | SF | Blocked Requests | Admitted Requests | Reallocation Procedures | Total Reallocations |
|---|---|---|---|---|---|
| 2 | 4 | 105 | 7 | 6 | - |
| 3 | 8 | 142 | 106 | 91 | - |
| 4 | 16 | 288 | 714 | 438 | 29 |
| 5 | 32 | 535 | 3426 | 1234 | 306 |
| 6 | 64 | 1065 | 14875 | 1798 | 1118 |
| 7 | 128 | 2073 | 62091 | - | 2925 |
| Total | | 4208 | 81219 | 3567 | 4378 |

**Table 3:** Sequential allocation and proposed reallocation (S.A.P.R.).

| K | SF | Blocked Requests | Admitted Requests | Reallocation Procedures | Total Reallocations |
|---|---|---|---|---|---|
| 2 | 4 | 105 | 7 | 7 | - |
| 3 | 8 | 142 | 106 | 92 | - |
| 4 | 16 | 288 | 714 | 382 | 39 |
| 5 | 32 | 535 | 3426 | 973 | 443 |
| 6 | 64 | 1065 | 14875 | 1265 | 1742 |
| 7 | 128 | 2073 | 62091 | - | 3737 |
| Total | | 4208 | 81219 | 2719 | 5961 |

**Table 4:** Proposed allocation and sequential reallocation (P.A.S.R.).

| K | SF | Blocked Requests | Admitted Requests | Reallocation Procedures | Total Reallocations |
|---|---|---|---|---|---|
| 2 | 4 | 105 | 7 | 7 | - |
| 3 | 8 | 142 | 106 | 93 | - |
| 4 | 16 | 288 | 714 | 389 | 23 |
| 5 | 32 | 535 | 3426 | 896 | 263 |
| 6 | 64 | 1065 | 14875 | 1049 | 679 |
| 7 | 128 | 2073 | 62091 | - | 2542 |
| Total | | 4208 | 81219 | 2434 | 3507 |

**Table 5:** Proposed allocation and reallocation (P.A.P.R.).

| k | SF | Reallocation Procedures | | | |
|---|---|---|---|---|---|
| | | S.A.S.R | S.A.P.R. | P.A.S.R. | P.A.P.R. |
| 2 | 4 | 7 | 6 | 7 | 7 |
| 3 | 8 | 99 | 91 | 92 | 93 |
| 4 | 16 | 610 | 438 | 382 | 389 |
| 5 | 32 | 1779 | 1234 | 973 | 896 |
| 6 | 64 | 1951 | 1798 | 1265 | 1049 |
| 7 | 128 | - | - | - | - |
| Total | | 4446 | 3567 | 2719 | 2434 |

**Table 6:** Simulation results – Number of reallocation procedures.

| k | SF | Total Reallocations | | | |
|---|---|---|---|---|---|
| | | S.A.S.R | S.A.P.R. | P.A.S.R. | P.A.P.R. |
| 2 | 4 | - | - | - | - |
| 3 | 8 | - | - | - | - |
| 4 | 16 | 38 | 29 | 39 | 23 |
| 5 | 32 | 458 | 306 | 443 | 263 |
| 6 | 64 | 1839 | 1118 | 1472 | 679 |
| 7 | 128 | 11152 | 2925 | 3737 | 2542 |
| Total | | 13487 | 4378 | 5961 | 3507 |

**Table 7:** Simulation results – Total number of reallocations.

## CLAIMS

1. Method for modulating an information signal in a telecommunication system, which communication system makes use of spreading codes in the modulation to discriminate between user signals, the codes being allocated for incoming requests by selection from one or more code structures having codes of different bit rates,
   c h a r a c t e r i z e d by the following steps
   a) noting the bit rate of a code to be allocated for an incoming request,
   b) determination of the availability of the different codes having the desired bit rate,
   c) allocating a code in accordance with pre-selected rules by taking the availability of the different codes into consideration in a way leading to an optimal use of the code structure(s).

2. Method of claim 1, c h a r a c t e r i z e d in that the incoming request is assigned to another code structure if it is considered in step a) that the transfer capacity would be exceeded.

3. Method of claim 1, c h a r a c t e r i z e d in that the incoming request is blocked if it is considered in step a) that the transfer capacity would be exceeded.

4. Method of claim 1, c h a r a c t e r i z e d in that a code of requested bit rate is allocated among free codes of requested level if it is considered in step b) that there is at least one available code of the requested bit rate.

5. Method of claim 4, c h a r a c t e r i z e d in that if there is more than one code of requested bit rate available, the code is allocated in step c) in accordance with pre-selected rules in such a way that the selection of a code to be allocated is performed in such a way that the codes preserving the highest possible number of available higher bit rate codes are prioritized.

6. Method of claim 5, c h a r a c t e r i z e d in that the selection of a code to be allocated among the prioritized codes is performed by maximizing the probability of future release of a higher bit rate code.

7. Method of claim 5 or 6, c h a r a c t e r i z e d in that the prioritizing of codes is performed by
determination of the unavailability degree of the shorter length codes relating to the available free codes of requested bit rate,
choosing the set of codes among the free codes having related shorter length codes with the highest unavailability degrees, and
repeating the foregoing step for related shorter length codes until the root code, and finally choosing a code from the resulting subset.

8. Method of claim 1, c h a r a c t e r i z e d in that reallocation is performed if it is considered in step b) that no codes of the requested bit rate exist.

9. Method of claim 8, c h a r a c t e r i z e d in that the reallocation is performed by
assigning the incoming request to an unavailable code, and
reallocating used related lower bit rate codes to release the assigned unavailable code.

10. Method of claim 9, c h a r a c t e r i z e d in that the preferred unavailable code is the one that minimizes the total number of changes of already allocated codes.

11. Method of claim 9, c h a r a c t e r i z e d in that the preferred unavailable code is the one that have the lowest number of assigned lower bit rate codes.

12. Method of claim 9, c h a r a c t e r i z e d in that the reallocation of used codes are performed either by allocation or reallocation in accordance with the same rules as the allocation of codes to an incoming request.

13. Method of claim 9, characterized in that the preferred unavailable code is the one that have the lowest unavailability.

14. Method of claim 9, characterized in that the preferred unavailable code in the reallocation is the one having the lowest number of assigned lower bit rate codes in its subtree, and if there are more than one such unavailable codes, choosing the one having the lowest unavailability level.

15. Apparatus to be used in a digital communication system, in which communication system a spreading code is used in the modulation to discriminate between user signals, the code being allocated from a set of codes of different bit rates in such a way that the highest possible number of higher bit rate codes are preserved, characterized by means for performing the steps described in any of claims 1 – 14.

16. Computer program to be used in a telecommunication system, in which communication system a spreading code is used in the modulation to discriminate between user signals, the code being allocated from a set of codes of different levels in such a way that the highest possible number of higher bit rate codes are preserved, characterized in that the following steps are carried out

a) noting the bit rate of a code to be allocated to an incoming call request,
b) determination of the availability degree of the different codes having the desired bit rate,
c) allocating a code according to the availability degree in accordance with an algorithm or a reallocation algorithm performing pre-selected rules.

17. Computer program of claim 16, further characterized by means for performing the steps of any of claims 2 – 14.

**ABSTRACT**

The invention is concerned with a method of the invention for modulating an information signal in a telecommunication system. The communication system makes use of spreading codes in the modulation to discriminate between user signals. The codes are allocated for incoming requests by selection from one or more code structures having codes of different bit rates. The method is characterized by the steps of noting the bit rate of a code to be allocated for an incoming request, determination of the availability of the different codes having the desired bit rate, and allocating a code in accordance with pre-selected rules by taking the availability of the different codes into consideration in a way leading to an optimal use of the code structure(s). The apparatus of the invention comprises means for performing the method of the invention. The algorithm of the invention performs the allocation method of the invention in form of a computer program in accordance with certain rules.

FIG. 2

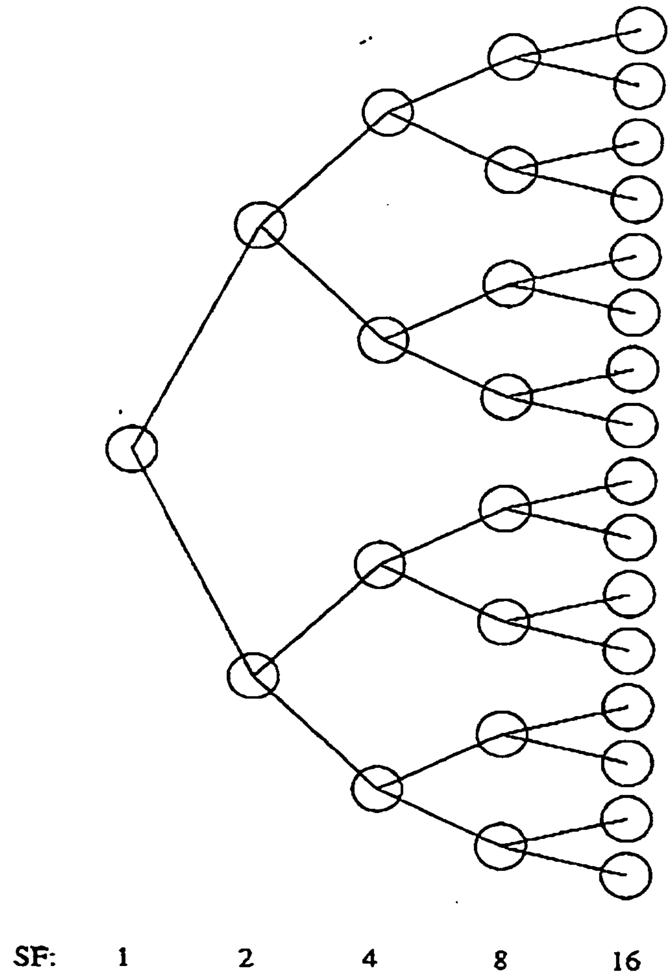


FIG. 1

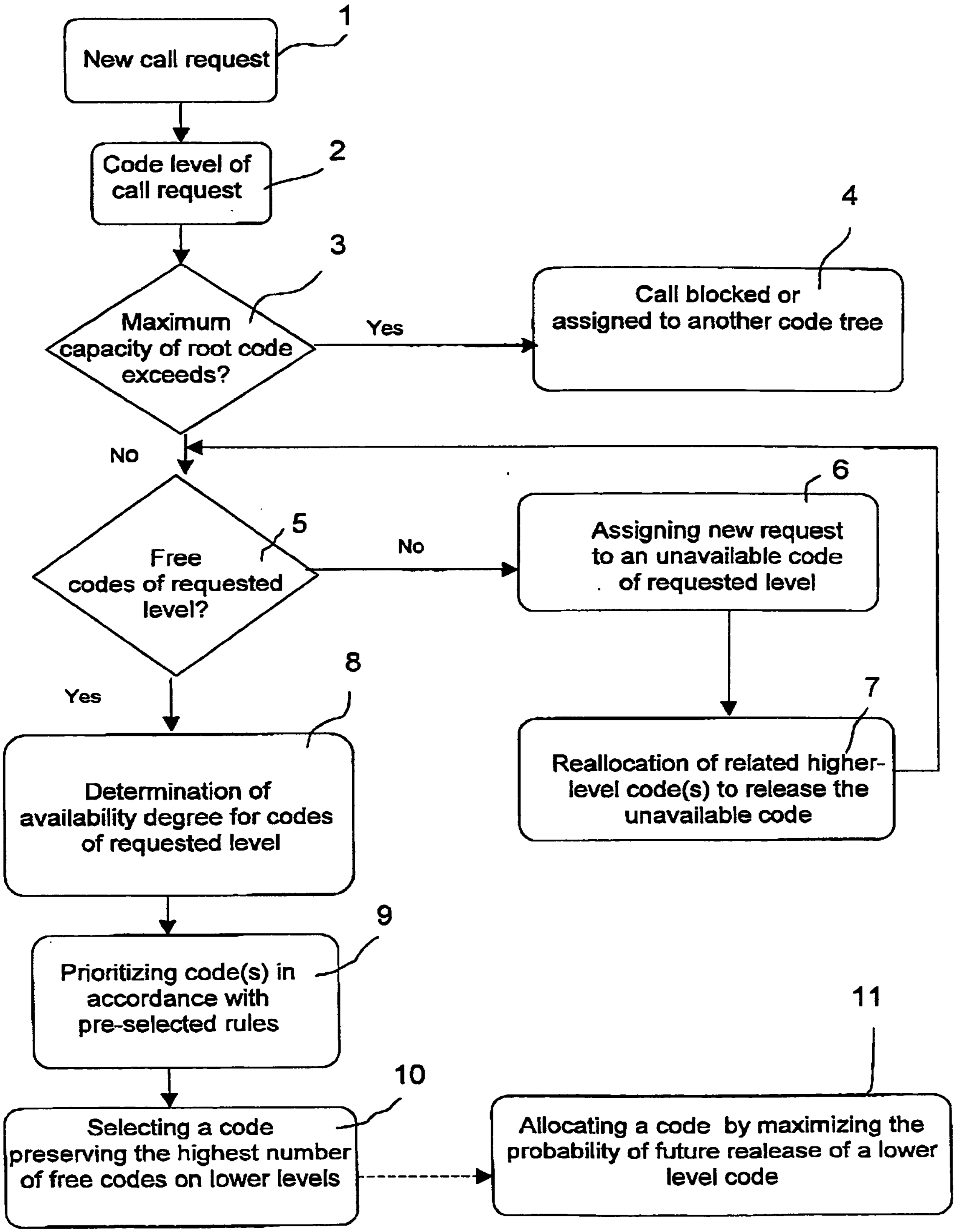
1
New call request
2
Code level of call request
3
Maximum capacity of root code exceeds?
Yes
4
Call blocked or assigned to another code tree
No
5
Free codes of requested level?
No
6
Assigning new request to an unavailable code of requested level
7
Reallocation of related higher-level code(s) to release the unavailable code
Yes
8
Determination of availability degree for codes of requested level
9
Prioritizing code(s) in accordance with pre-selected rules
10
Selecting a code preserving the highest number of free codes on lower levels
11
Allocating a code by maximizing the probability of future realease of a lower level code

FIG. 2

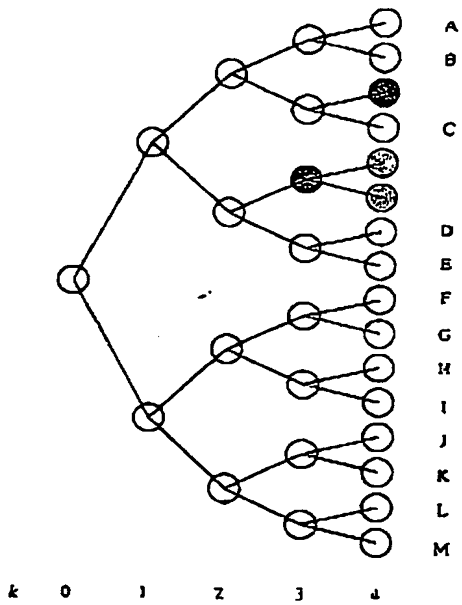


FIG. 3

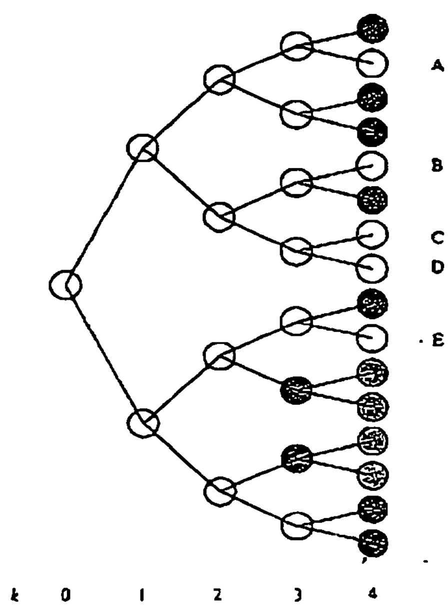


FIG. 4

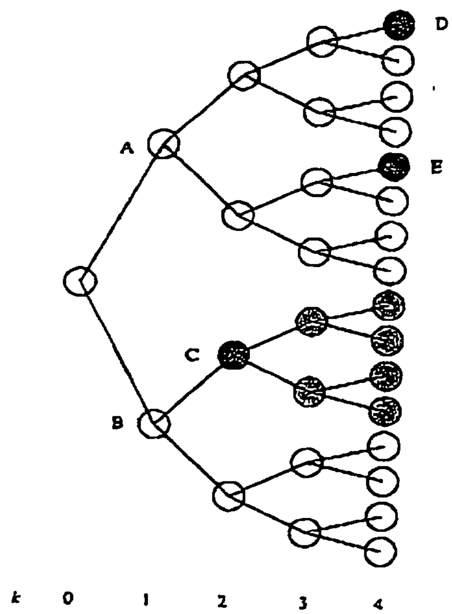


FIG. 5

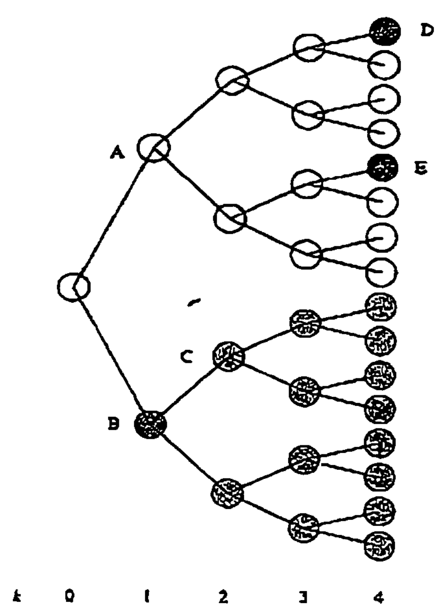


FIG. 6

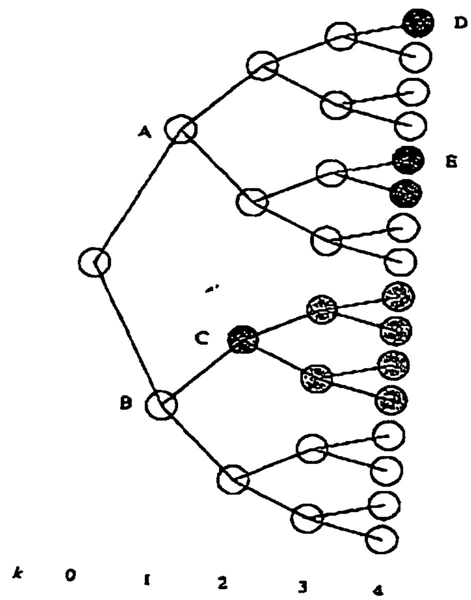


FIG. 7